THE INSTITUTE OF PHYSICS
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BULLETIN

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CONTENTS

	Page
NOTICES TO MEMBERS	141
LIVERPOOL AND NORTH WALES BRANCH: INAUGURAL MEETING	142
EDUCATION THROUGH PHYSICS By Professor F. A. Vick	143
THE PLACE OF PHYSICS IN A SCHOOL CURRICULUM By A. W. Barton	151
YORKSHIRE BRANCH DISCUSSION ON TRAINING FOR INDUSTRY	163
REVIEWS OF BOOKS	167
NEWS OF MEMBERS	171
LONDON BRANCH SUMMER MEETING	172
APPOINTMENTS VACANT	ii

The Bulletin is not intended for general circulation: your copy should not therefore be passed to a library.

APPOINTMENTS VACANT

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

The British Coal Utilisation Research Association invite applications from graduates for research on flue-gas corrosion and deposit formation in boilers and other plant. The work involves the running of experimental plant and the carrying out of some tests at power stations. A sound knowledge of inorganic chemistry and physics, and the ability to lead a research team are required. Some metallurgical experience would be an advantage. Starting salary £900 to £1200 p.a. according to age and qualifications. Superannuation Scheme. Apply in writing to Assistant Secretary, Ref. B.32, B.C.U.R.A., Randalls Road, Leatherhead.

The British Thomson-Houston Company Ltd., has vacancies in its Research Laboratory at Rugby for honours graduates in physics or electrical engineering to join a team engaged in the development of microwave electronic valves. The work is chiefly concerned with the investigation of the fundamental operating mechanisms of established devices such as magnetrons and klystrons and the evolution of new types of microwave oscillator. The team operates in a new laboratory, well equipped and provided with all constructional and engineering facilities. Applicants are invited to send details of their age and qualifications to The Director of Research, British Thomson-Houston Company Ltd., Rugby, quoting Reference No. DR.4.

The Electrical Research Association invite applications from graduates in physics for appointments in connection with fundamental investigations on the thermal behaviour of buildings, the storage of electrical energy as heat, and thermodynamic problems in new applications such as the heat pump and the use of solar energy.

Positions are available for young graduates as well as for those with post-graduate training and experience. Salaries are based on experience and qualifications and permanent employment comes within the F.S.S.U. Applications to be made to the Director, E.R.A. Laboratories, 5 Wadsworth Road, Greenford, Middlesex.

Wool Industries Research Association

Physicist (male), good honours degree or A.Inst.P., required for research on servo control mechanisms. Previous knowledge of this type of work is not essential but some research experience would be an advantage.

Initial salary will be in the range £560 to £1,125 p.a., depending on age and qualifications, with F.S.S.U. benefits. Applications to Wool Industries Research Association, Torridon, Headingley, Leeds, 6.

An interesting vacancy exists at the York factory of **Cooke, Troughton & Simms Ltd.,** for a graduate in physics or mathematics who would like to specialize in optical design. The selected applicant would receive a course of instruction in technical optics with a view to his ultimate appointment as optical designer with the Company. A generous salary can be offered during the training period. Applicants should have completed or be exempt from National Service. Apply in writing, giving all relevant particulars, to the Personnel Officer, Cooke, Troughton & Simms Ltd., Haxby Road, York.

The British Iron and Steel Research Association

Physicist or **Fuel Technologist** required by the above Association for an interesting position in the Steelmaking Division of the Association in Sheffield. Problems of steelmaking furnace design and operation involving combustion and aerodynamics, instruments and control are dealt with and the job calls for direct application of laboratory investigation to works practice thus offering wide opportunities. Candidates should have a degree or equivalent qualifications in physics or fuel technology, and should be interested in research. Age range 24–28 years. Salary according to age, qualifications and experience. Post is superannuated under the F.S.S.U. Written applications only quoting " Steelmaking " to Personnel Officer, B.I.S.R.A., 11 Park Lane, London, W.1.

Radiological Protection Service (Ministry of Health and Medical Research Council), Downs Hospital, Cotwold Road, Sutton, Surrey, require scientific staff for

(*a*) Research in radiation protection problems ; initially, development of equipment measuring radioactivity in human beings ;

(*b*) Supervision of group on radiation-monitoring services, and development of improved techniques of radiation measurement ; may be required to carry out radiation surveys ;

(*c*) Development and maintenance of electronic equipment for radiation measurements ;

(*d*) General radiation monitoring duties with advice on plans of new or modified radiological departments ; to carry out radiation surveys.

Applicants for (*a*), (*b*) and (*c*) should have at least good second class honours degree in Physics ; for (*d*) science degree with considerable laboratory experience preferably in radiation field. Salary (according to age and experience) at point in scales : (*a*) £1,270 × 50 – 1,470, (*b*) £950 × 50 – 1,250, (*c*) £565 × 25 – 690, (*d*) £925 × 25 – 1,050. Superannuation provision ; children's allowances.

Candidates should write to Mr. W. Binks, Director of the Service, giving full details of academic and subsequent careers and names of two professional referees.

Joseph Lucas Limited, Burnley, require a **Research Metallurgist** or **Physicist** (Graduate) for work on the fundamental properties of materials for high temperature applications. Some experience of vacuum and metallographic techniques desirable. Salary according to age and experience. Write giving full details to Personnel Department, Hargher Clough Works.

The British Thomson-Houston Company Ltd. has vacancies in its Research Laboratory at Rugby for honours graduates in physics or electrical engineering to work on problems connected with the development of gas discharge control valves such as thyratrons, ignitrons, etc. The work is varied in character and demands an interest in gas discharges, together with some knowledge of electronics and valve circuitry. Applicants are invited to send details of their age and qualifications to The Director of Research, British Thomson-Houston Company Ltd., Rugby, quoting Reference No. KH.

(*Continued on page iii*)

City of Leicester Education Committee
College of Technology and Commerce

The Newarke, Leicester
Principal : R. E. Wood, M.Sc., F.Inst.P.

Applications are invited for the post of full-time Assistant, Grade B, in the School of Physics and Applied Science. Candidates should be graduates, preferably with experience in some branch of applied physics.

Salary : Burnham Technical Scale for Grade B Assistants—£525 × £25 to £820 per annum—plus appropriate allowances according to qualifications and training and increments for approved teaching and industrial experience.

Forms of application and further particulars may be obtained from the Registrar, to whom completed forms should be returned not later than the 24th June, 1955.

Elfed Thomas,
Director of Education.

The British Cotton Industry Research Association

There is an important vacancy at the Shirley Institute for a man to undertake fundamental research on loom mechanisms, while also interesting himself in the development of a new loom. It is thought that a mechanical engineer with an interest in research on high speed mechanisms might best fill the vacancy, but applications are also invited from physicists and mathematicians.

The minimum qualification for this post is a Second Class Honours degree. Applications are invited from those doing National Service, from students who are taking degrees in 1955, and from other people who expect to be available before the end of 1955.

Salaries for young graduates are in line with those offered by the Scientific Civil Service, and £850 per annum will be paid to a more experienced graduate. The post carries superannuation benefits under the Federated Superannuation Scheme for Universities. Experience of textiles is not essential for this post.

Applications giving full particulars of qualifications and career should be sent to Dr. F. C. Toy, Director of Research, Shirley Institute, Didsbury, Manchester, 20.

The United Kingdom Atomic Energy Authority, requires a **Manager** for the Criticality, Health Physics and Safety Group at their Dounreay works, Caithness, Scotland, to be responsible to the Works General Manager for the efficient and satisfactory operation of the Health Physics Department. This department will advise the Works General Manager on matters of criticality, disposal of radioactive materials and decontamination ; have responsibility for general works safety including special hazards such as liquid metals and will be required to work in close connection with the Medical Department. Candidates must have an honours degree in physics. Experience in management and the handling of problems associated with radioactive materials and radiation will be an advantage.

Salary £1,425 – £1,620 p.a. All new entrants under the age of 55 automatically join the Authority's Contributory pension scheme. Housing accommodation available within a reasonable time if married.

Send postcard for application form to **United Kingdom Atomic Energy Authority,** Industrial Group Headquarters, Risley, Nr. Warrington. Ref. 993 must be quoted.

E.M.I. Engineering Development Limited
Senior Engineer/Physicist

An attractive vacancy exists at this Company's Feltham laboratories for a **Senior Engineer/Physicist** to work on a number of theoretical problems in the G.W. field. The man we are looking for will be qualified and will have had some related experience. His main responsibility will be to devise series of critical laboratory and field experiments in connection with weapon developments. An attractive salary will be offered to the successful applicant for this pensionable post, and the prospects in this active and expanding Company are excellent. Please send your first reply to, Personnel Department, (ED/238), E.M.I. Engineering Development Ltd., Blyth Road, Hayes, Middlesex.

Applications are invited for vacancies in the plastics and rubber sections of the Research Laboratories of **Monsanto Chemicals Limited,** Fulmer, Bucks.

The work undertaken covers investigation into scientific and technical problems associated with the use of plastics and of rubber chemicals and the posts offer good opportunities to young men with ideas and ability.

Applicants should possess a good degree in Chemistry, Physics or Chemical Engineering, or alternatively good technical qualifications, and for preference should have had research or industrial experience.

Details of age, education, qualifications and experience should be sent to the Chief Personnel Officer, Monsanto Chemicals Limited, 8 Waterloo Place, London, S.W.1.

The British Northrop Loom Company Ltd.
Blackburn

Opportunities are available in the expanding Research and Development Department of this progressive Textile Machinery firm for engineering or physics graduates. Previous research experience is not essential, but candidates must have a wide general scientific knowledge, and be prepared to apply this to previously unexplored fields, working under the supervision of the senior scientific staff. The posts offer excellent prospects with salary according to qualifications and experience, and a generous superannuation scheme. Apply in the the first instance, to the Secretary of the Company.

Physicist for research associated with optical, high vacuum, and precision engineering. Applicants should have an honours degree in physics coupled with a sound knowledge of research procedure and ability for practical experiment. Training will be given in the special techniques required.

Applications stating age, qualifications and experience to be addressed to The Secretary, **Barr and Stroud Limited,** Anniesland, Glasgow, W.3, quoting Ref. 771/T-15.

The British Thomson-Houston Co. Ltd., have vacancies in their Research Laboratories for **physicists** with a good honours degree or its equivalent. Applicants should have an interest in one of the following fields :

(*a*) Vacuum physics ;
(*b*) Gas discharges ;
(*c*) Photo-conductive materials.

Previous research experience is not essential.

Apply, quoting Reference PD, and stating age, qualifications and experience to The Director of Research, British Thomson-Houston Co. Ltd., Rugby.

(*Continued on page v*)

THE INSTITUTE OF PHYSICS

Vol. VI, No. 7 **BULLETIN** JULY, 1955

NOTICES TO MEMBERS

British Nuclear Energy Conference

The Board of the British Nuclear Energy Conference, of which the Institute is one of the five constituent bodies and of which details were given in the June *Bulletin*, has arranged a Lecture Symposium for Wednesday, November 30 next, in London, to be opened by our President. Admission will be by ticket ; tickets may be obtained by members on application to the Secretary of the Institute and will be issued only for members' personal use. Synopses of the lectures to be given will be published later.

The first issue of the *Journal* of the British Nuclear Energy Conference will be published in January, 1956, and will contain the lectures and discussion of this symposium. The retail price of this journal will be 60s. annually, but members of the five constituent bodies will be entitled to purchase copies at half the retail price.

Graduateship Examination

The Institute's Graduateship Examination was held in London (The Institute's House), Birmingham (College of Technology), Salford (Royal Technical College) and Paisley (Technical College), from June 20 to 23 inclusive. The practical examination was held on June 24 at The Polytechnic, Regent Street. A full report on the examination will be published in a later issue of the *Bulletin* ; it is intended that the question papers shall also be published in the *Bulletin* this year as they may be of considerable interest to members who have assistants seeking professional qualification and to students. The collected papers can now be obtained at 3s. the set on application to the Institute.

The present and future demand for physicists in Government service and Industry

The articles by Sir Owen Wansbrough-Jones and Mr. O. W. Humphreys with the discussion upon them, published in the May *Bulletin*, are now obtainable as reprints at a cost of 2s. each. Application should be made to the Deputy Secretary.

International Conference on Fatigue of Metals

The Council of the Institution of Mechanical Engineers are arranging an International Conference on Fatigue of Metals to be held from Monday, September 10, to Friday, September 14, 1956, inclusive. Sessions for the delivery of papers will be held daily from 10.00 a.m. to 12.30 p.m. and from 2.30 p.m. to 5.30 p.m.

It is hoped to obtain up to sixty papers covering the whole field, and these will be divided into groups, the papers in the various groups being presented for discussion in abstract form by Reporters.

Copies of the papers will be available in advance of the meeting, and the Proceedings of the Conference, containing the papers and discussion, will be published by the Institution in due course.

LIVERPOOL AND NORTH WALES BRANCH : INAUGURAL MEETING

The inaugural meeting of the Liverpool and North Wales Branch was held in the Department of Electrical Engineering, University of Liverpool (by permission of Professor J. M. Meek) on May 19th. About 110 members and guests attended for tea. A short business meeting followed, at which Professor E. A. Owen (*Fellow*) was unanimously elected as Chairman. The other officers and members of the Branch Committee, who represented a wide range of interests in local industry, the Atomic Energy Establishment, at Capenhurst and the Universities, were also elected. The attendance at the business meeting was about 170 ; science teachers from schools, local industrial laboratories, Capenhurst, The University College of North Wales (Bangor) and the University of Liverpool were all strongly represented.

The inaugural lecture was delivered by Professor Kopal of the Department of Astronomy, University of Manchester. " The Physics of the Sun " is a subject of wide interest, and the lecturer treated it in a most stimulating and successful manner. In particular, the short film shown by Professor Kopal of solar prominences aroused an enthusiastic interest. The Branch is extremely grateful to Professor Kopal.

The President was represented at the meeting by Professor Ibbs, Senior Vice-President. The Secretary of the Institute also attended. The Manchester Branch was represented by Dr. Drummond, Honorary Branch Secretary.

J. D. Craggs.

EDUCATION THROUGH PHYSICS *

By Professor F. A. VICK, O.B.E., Ph.D., F.Inst.P.
(*University College of North Staffordshire, Keele*)

I would like to begin by quoting from a lecture given in the U.S.A. by Professor L. A. Du Bridge on " The Goals of University Research."

" We need . . . to re-emphasize the value of the enquiring mind. How few people there are who think of the university as primarily the meeting ground for inquiring minds. More people think of the professor as a person who earns an easy—and deservedly meagre—living by reading dull lectures from dusty notes before drowsy students. Yet these same people send their sons and daughters to college in the belief that from these same courses they will learn to make a handsome living, as well as learn to be good people, patriotic citizens ,and wise parents. The college graduate is supposed to know all the facts about the history of the United States, and not too much about the rest of the world ; he should be alert, suave, a good public speaker, and an acceptable member of the best society, and a good Republican. As he goes into business or industry, he must be humble enough to do the most menial tasks, but must never be caught uninformed on the most difficult problem. He should—but I need not extend the list of attributes which are variously expected of the students who have studied under these dull professors. The only attributes which are usually not insisted upon are that the student should be inquisitive, that he be thoughtful, that he have a zest for life ; and that each of these qualities shall have been appreciably sharpened or enhanced by the college experience. We recognize that in training a prize-fighter he must be toughened by strenuous exertion, and matched against skilled opponents. But we are afraid of intellectual toughening. We are fearful to let our young people wrestle with the toughest problems and ideas, thus learning for themselves how to find the truth—the truth about science, philosophy, economics and politics.

It is this failure to understand the essential role of colleges and universities as toughener of the mind, stimulators of curiosity, as the ringside of intellectual conflict that makes for much of the unjust, exasperating, and damaging criticism which higher education is now undergoing."

Extending Professor DuBridge's criteria, what qualities do we and the world expect of a well-educated man ? That he should have a tough and inquiring mind, able, and indeed anxious, to tackle new problems, new situations. That he should be creative, not hidebound, independent and not relying solely on the minds of others. That he should be well informed generally and really knowledgeable about

* A lecture given to the Institute's Education Group at the Institute's House on April 15, 1955.

certain subjects or parts of subjects. That he should appreciate spiritual and aesthetic values. That he should be intellectually honest, able to recognize a hard fact, and not afraid to give up preconceived ideas in the face of demonstrable proof. That he should be able to express himself clearly, convincingly and concisely in writing and in speech. That he should be able to live with and collaborate with others, showing the tolerance which arises from an understanding of studies and beliefs other than his own, but not tolerance of slovenliness of any kind. That he should exhibit the qualities of perseverance and humility, and above all, of judgement.

I am not going to pretend that all these qualities can be acquired solely from courses in physics, though I do believe that most if not all of them can be developed by contact with some physicists, such as those who take the trouble to attend conferences like this, especially if there are opportunities for lively discussion and other corporate activities outside the lecture room and laboratory. I also believe that we can do a great deal more in the planning of and teaching in our courses to educate students' minds than is sometimes done. Moreover, I think that courses in the physical sciences can make contributions to the education of a mind which few other subjects can. Though I shall speak from the point of view of a University teacher, I hope that much of what I wish to say will be applicable to schools and to technical colleges also.

Consider the traditional physics courses in the VIth forms of schools and the first two years at a university. They are often admirably designed to give a student the information that every self-respecting physicist should know, and to train him in the basic techniques. For convenience, the subject is divided into compartments, Heat, Light, Sound, Electricity, etc. The text books and lecture courses give, in logical order, those developments which have been accepted into the body of knowledge of the subject. The problems set are largely drill problems on those parts of the subject just learned. All this is quite essential, particularly numerical problems, but is it enough ? After all, physics in real life is not like that. We do not wish to perpetuate the habit easily acquired at school, i.e. if a problem is given to us, try to find one like it in the textbook. Some people say that experience in investigation can be gained only by postgraduate research or in industry. Others say that not much can be done until the final honours year where, particularly in the laboratory, problems of the research type can be tackled. I believe that one cannot start too early in exercising and toughening the mind. It is quite easy to devise problems the answers to which do not depend on advanced physics but do need real understanding of fundamentals, the ability to formulate a question, and a flexibility of mind. For example :—

(*a*) Why is it that on looking into a plane mirror we appear to be turned left for right but not upside down ?

(*b*) Explain why walls above radiators go black. (This can soon lead into problems of real importance to industry).

(*c*) How would you measure the temperature of a live fly ?

(*d*) Design a jug or a saucepan which will pour well without dripping. Could your design be made ?

I find that most students are stimulated by this kind of problem, and that they soon think of others to ask themselves—or me. Of course, many teachers do use this method of exercising the mind, and a few textbooks include such problems, though in this respect perhaps American textbooks are better than our own. In the laboratory, too, we can do a great deal, especially if we can introduce into the same experiment techniques from several branches of physics and if the learning of the techniques can be made more interesting to the student by widening the scope of the measurements (e.g. combining the change of resistance of a wire with strain with the measurement of Young's Modulus). I believe that well-planned laboratory work is essential in any systematic course of physics. A student must learn by experience how real things behave. It is sometimes said that one of the most valuable aids to a chemist is his nose, and textbooks cannot be used to train noses ! A physicist can learn a lot through his eyes, fingers and ears, provided these serve an educated mind. Part of learning how to plan experiments consists in doing them.

Another impression a student easily gains from the orthodox course and textbook is that, though the subject may be difficult to him, great minds find it easy and that the subject developed in the nice logical order so clearly set out in the books. You will probably remember the illuminating remark by Helmholtz (quoted by Beveridge, *The Art of Scientific Investigation*, p 60).

" Any pride I might have felt in my conclusions was perceptably lessened by the fact that I knew that the solution of these problems had almost always come to me as the gradual generalization of favourable examples, by a series of fortunate conjectures, after many errors. I am fain to compare myself with a wanderer on the mountains who, not knowing the path, climbs slowly and painfully upwards and often has to retrace his steps because he can go no further—then, whether by taking thought or from luck, discovers a new track that leads him on a little till at length when he reaches the summit he finds to his shame that there is a royal road, by which he might have ascended, had he only had the wits to find the right approach to it. In my works, I naturally said nothing about my mistakes to the reader, but only

described the made track by which he may reach the same heights without difficulty."

Textbooks, of course, describe only the royal road. It is occasionally worthwhile to interrupt the logical flow of lessons or lectures to show, perhaps by means of a case study, by what devious routes some of our accepted theory has been reached. Though I am convinced that to teach most of physics in a historical order is not the right way (the history of the subject is fascinating *after* one has learned some physics), at times the historical approach is most valuable. It is stimulating, too, to read from time to time autobiographies or biographies of great scientists, and I sometimes prescribe such reading for the vacation.

May I here make a plea that all physics students should, from time to time, read original papers. They should learn that some textbooks are copied from a variety of previous textbooks (quite naturally) and that, years ago, a writer placed his own interpretation on an original paper, an interpretation which might be significantly altered to-day and in the light of the reader's present interests. Some of the classical papers have been reprinted in various places and are fairly easily accessible.

One of the ways in which physics differs from many other subjects is that it is truly progressive. To quote from George Sarton :

" The Saints of to-day are not necessarily more saintly than those of a thousand years ago : our artists are not necessarily greater than those of early Greece, they are likely to be inferior ; and, of course, our men of science are not necessarily more intelligent than those of old ; yet one thing is certain, their knowledge is at once more extensive and more accurate. The acquisition and systematization of positive knowledge is the only human activity that is truly cumulative and progressive."

Some remarks by Professor Polanyi are also relevant :

" The consensus prevailing in modern science is certainly remarkable. Consider the fact that each scientist follows his own personal judgement for believing any particular claim of science and each is responsible for finding a problem and pursuing it in his own way ; and that each again verifies and propounds his own results according to his personal judgement. Consider moreover that discovery is constantly at work, profoundly remoulding science in each generation. And yet in spite of such extreme individualism acting in so many widely disparate branches, and in spite of the general flux in which they are all involved, we see scientists continuing to agree on most points of science. Even though controversy never ceases among them,

there is hardly a question on which they do not agree after a few years' discussion. (*Science, Faith and Society*, p. 36.)

These points, too, can be brought out in appropriate places, and are important in showing some of the ways in which the sciences differ from other subjects. But how many students appreciate these characteristics of science ?

It is often assumed that, after being subjected to the normal physics course, a student will appreciate all the attributes of the so-called scientific method. It is true that all earnest students of physics cannot help picking up some of the methods of thought and techniques of a scientist, but I am sure that, at an appropriate stage, it is valuable to discuss with him the methods of scientific investigation and thought. I am not one of those who are content to let a philosopher tell them how they go about their work, though I do value discussions with philosophers about some of the implications of physics and methods of thought. Neither do I think that many of the descriptions in the literature of the methods of scientists are at all adequate. Reading some of them, one gets the impression that one has only (*a*) to formulate a question, e.g. to test a hypothesis, (*b*) design an experiment, (*c*) carry out the experiment, and the answer will be immediately obvious. In most cases, nothing could be further from the truth. To extend the formulation of Graham Wallas in another connexion, the essential processes in an investigation are :—(i) preparation, (ii) incubation, (iii) illumination (iv) verification. Together with the meanings of fact, hypothesis, law, etc. (and how these meanings differ in physics from those used in mathematics, economics, etc.) one can illustrate these stages from the subjects students have studied already and show that inspiration and imagination are just as essential in science as in any other creative activity of the human mind. Yet, in how many textbooks of physics is this made clear ? Sir Cyril Hinshelwood expressed it very well in his presidential address to the Science Masters' Association in Oxford in 1953.

" Science is not the dryly syllogistic handling of obvious facts. It is an imaginative adventure of the mind seeking truth in a world of mystery."

We must encourage our students to use their imaginations, as well as showing them the imaginative content of science. We must show them that progress in science is not always in a logical order. There are often leaps forward, not completely verified until much later. Sometimes a hypothesis which proves to be wrong is valuable because of the stimulus it gives to further work.

Especially in their final honours year, we must do more. Students must know what it means to reach the frontier in one or two places,

I do not think it really matters at which places, provided the students are stimulated by an enthusiastic physicist who has soaked himself in that branch of the subject, and preferably, contributed to it, and provided that the final year is not too narrow. It should include some of the abstract conceptions in which physics is so rich (contrary to popular belief). They must know from experience how to plan and carry out an experimental investigation, however small. Here some instruction on the principles of design of experiments and instruments, and on the treatment of experimental observations, is a great help.

We must remember, too, some of the other essential tools of a physicist, such as the writing of reports, how to look up a subject and to use a library, how to prepare an abstract, and to read a paper, as well as the essential techniques of mathematics and practical work. But even when all this is done, he may still be vulnerable to the criticism of Professor Dingle :

" It is one of the paradoxes of modern life that while—on the material and intellectual side, at any rate—it is dominated by science very few people have any clear idea of what science is. The word conjures up a vague image of machinery and atomic bombs, coupled perhaps with something unintelligible about mathematics and the vast extent of space, but very few can give even an approximately accurate definition of science or know anything at all about the way in which it originated and has come to take the commanding position which it now occupies in our civilization. This is true not only of the rank and file but also of the average scientist. He understands what he is doing about as well as a centipede understands how he walks. He does his job well enough, and he may know the immediate object of his efforts, but how it has come about that these efforts are called for, what is their significance in relation to life as a whole, and what will be their ultimate effect, are matters on which his innocence is beyond reproach. There are those who maintain that this is as it should be, and that if the centipede tried to understand walking he would cease to be able to practice it. This argument is convincing to those who emulate centipedes." (*Universities Quarterly*, August 1952.)

> " The centipede was happy quite
> Until the toad, for fun,
> Said : Pray which leg comes after which ?
> He lay distracted in a ditch
> Considering how to run."

Not only do we wish the physicist to understand the origin and growth of his subject, but also the interactions of it with other activities such as philosophy, economics, religion and the development of civilization as we know it. Though his physics teachers can do much if they are

sufficiently thoughtful and well educated and if they have contact with students outside the lecture room, here we do need the help of our colleagues. We cannot always invite Canon Raven to introduce a discussion, but we can stimulate discussions. We can also say something about the organization of physics in this and other countries, and of the scope of physics as a career.

I have not said much about the physics courses themselves. I think we all realize the need for emphasis on principles, for synthesis between different sections of physics, and for a conscious purpose behind our practical teaching so that it is more than a collection of experiments. In a word, we must continually revise our courses in the light of a growing and changing subject.

We must remember, too, that the education of a physicist is a long and continuing process, starting with childish experiment in the home, followed by more formal courses at school and then university or technical college, and succeeded again by postgraduate training and experience. We must decide at what stages the various steps in the educational process should be introduced.

So we can ensure that there is a good deal of education through physics : an understanding of some of the mysteries of Nature, enabling a physicist to be of service to his fellow men. Logical thought, and an ability to think quantitatively. Intellectual courage and honesty, the recognition of facts (at any rate, scientific facts). Experimental skill, and often the joy that goes with the constructive use of the hands. An inquiring mind which has retained some of the curiosity of the young. The ability to tackle new problems and to exercise judgement (cf. the success of scientists in operational research). Clarity and precision of expression in speech and in writing. The ability to handle abstract ideas. I think, too, that a student of physics can improve his sense of aesthetic values to some extent. From the vantage point of his subject he may observe and study the influence of physics on other fields of human endeavour.

Above all, his close study of the workings of material things from atomic nuclei to the universe itself will have induced a feeling of humility and wonder. He will appreciate all the more the things of the spirit.

All I have said applies, I hope, to courses for students aspiring to become professional physicists. Much of it should apply to subsidiary courses, not only for the scientist but also for students of engineering, medicine, music and the humanities. Even for the technologist, physics is not just a tool, but a contribution to his education.

Finally, I would like to return to one of the points with which I began. I believe that the physical sciences as they can now be taught,

freed from some of the mechanistic outlook of the late nineteenth century, contribute something to the education of the whole mind that no other discipline can. Moreover, it is a contribution which is specially valuable in a world which is increasingly dominated by science and technology.

Should we not now consider a well-designed and thorough course in physics not only as a preparation for the profession of physics, for many other branches of science and for technology, but also as the core of an education which could form an alternative to Greats or Modern Greats (for example) ? Not physics alone, but as one of the major subjects taken by some people who will later become our best civil servants, leaders in Industry, local government officials, politicians (and even headmasters !). If we wish to do this, we physicists must look very closely at the courses we teach.

THE PLACE OF PHYSICS IN A SCHOOL CURRICULUM

By A. W. BARTON, M.A., B.Sc., Ph.D.
(*Headmaster, City of London School*)

This section of your programme is headed " Physics in a Liberal Education." What do we mean by " education " ? I do not think we can improve on what Whitehead, the great philosopher, said about it in his book, *The Aim of Education :* " The boy is a growing person, and education is the guidance and stimulation of this process of self-development."

Then, what do we mean by a " liberal " education ? Surely that means an education which is directed not just to enable a boy to earn his living or justify his existence in a materialistic sense but at teaching him how to live as distinct from merely gaining a living. A liberal education is one which will produce a cultured person. What is culture ? " Culture is activity of thought and sensitiveness to beauty and humane feeling."

Where does physics come in this, in the guiding and stimulation of this process of self-development and in producing activity of thought and sensitiveness to beauty and humane feeling ? Physics is a branch of science, which arises from man's intuition to observe and analyse, and as Whitehead says in his book, *Science and the Modern World*, it is one of the two or possibly three most powerful intuitions of the human spirit. There is a contrast, of course, between science, the intuition to observe and analyse, and the humanities, which could perhaps be said to be the study of language and ideas, particularly ideas about men or about man and his relation to other men and to his Creator.

In a secondary education—in relation to the school curriculum I shall not say anything about the primary stage, which is really concerned with reading, writing and arithmetic—in the first stage we try to open to the boy or girl the doors to the various rooms of knowledge so that they can see what sort of things are to be known and which of these things, if any, appeal to the boy or girl. One of these rooms is labelled " Physics," and this would appeal to a few of those who have this intuition to observe and analyse.

When you open this new world to them they make an instant response to it. It is a fascinating thing as a schoolmaster to teach a boy of 13 and watch his reaction as you bring some of the facts and some of the concepts of physics before him and see how he instinctively responds to them and enjoys them and makes his own little contributions to their elucidation and understanding.

But what about the others in whom there is not very much instinct to observe and analyse ? My experience leads me to the conclusion

that at this first stage of secondary education between the ages of 11 and 16 the interests and abilities of the boy or girl are not sharply differentiated, and the really able boy will probably do just as well at physics as he will at Greek and will take equally to both of them. Furthermore, at this first stage in his education, the future classic will take quite an interest in the elementary concepts of physics. This, you see, corresponds to the stage that existed 100 or 120 years ago when a man like Whewell, the famous Master of Trinity, could be a first-class Classic and a first-rate scientist, when Kelvin could learn classics until he was 15 or 16 and then, having learned it all, turn over to mathematics and physics. We know what he did in that respect ; he created the subject of physics. Those days are over now, but they are reproduced in a small way in the early stages of the secondary school curriculum.

I suggest that the future specialist in the humanities should learn some science in general and some physics in particular in the first stage of his secondary education. As a headmaster, I have had to think of the problem of why should there be some science in the curriculum, why should there be some English in the curriculum and why should there be some classics in the curriculum. All boys and girls should learn some science although they are not going on to do science at the university, and for this reason. There is no need for me to labour to The Institute of Physics how physics in particular and science in general have revolutionized our material environment, and, more than that, have shaken the foundations of philosophy and religion. Everybody has got a religion when he grows up. Everybody has got some god. My own impression is that the god of the majority of Englishmen to-day is luck because they spend a lot of money each week on the football pools. But I was interested to hear of a remark by the caretaker of Downe House, Charles Darwin's home in Kent, to some visitors to whom he was showing the house. He described it as " the house of Charles Darwin, the man who showed that the Bible is wrong." That is what physics in particular and science in general have done to religion. They have undermined the religious faith of the ordinary, average person. That is one reason why science must be part of the curriculum of those who are not going to be science specialists, because they must understand something about this new branch of knowledge, what it can do for civilization and what its limitations are. For there is now another danger to face. In the Middle Ages when the human race was rather weighed down by its problems it turned intuitively to the church for solution. People would expect some *ex cathedra* pronouncement from the Pope, which they would follow in the certainty that their problems would be solved and their anxieties relieved. This function of the church has now been taken over by science in the opinion of the mass of the population. People now expect an

ex cathedra announcement from the Director of the Atomic Energy Research Establishment, or the President of the Royal Society, or—dare I say it ?—the President of The Institute of Physics. Therefore, it is most important that these future citizens should know what science is, and just what it can do, and—perhaps even more important—what it cannot do. I do not believe that science has shown that the Bible is wrong at all. I think it has shown the Bible's real message more clearly to us, but it has not shown that it is wrong. These then are some of the reasons why there should be some physics as part of the general education of every boy, those who are going to specialize in science and those who are not. Then when the boy grows up, as a citizen in a democratic community where he has a vote to exercise, he will exercise the vote more intelligently. Remember that hundreds of millions of pounds are now being spent by the Ministry of Supply and other Government Departments on science, and it will rest in the hands of these ordinary citizens whether this money is spent intelligently and whether science is given a proper and a fair chance. They cannot exercise their vote intelligently unless they have some little first-hand contact with science and understand what sort of things it can do and what sort of things it cannot do.

Having decided why physics should form part of the general education of all boys and girls, we must now decide what sort of physics we ought to do in this first stage of secondary education ? We can agree that those who find that they like physics during this first stage of secondary education, and want to make science their life's work, will go on to do a three-year course of advanced physics in the sixth form—what we in the schools call advanced physics and what the universities call elementary physics—and there we lay a serious foundation of a study of the subject.

What sort of physics are we to do in this course of general education ? It must be a course complete in itself, not the first part of a course to be completed in the sixth form or at the university. I suggest that there are three guiding principles in framing the course. The first one arises from the fact that we are trying to teach boys and girls, not young men and women as you are in the university. We in the schools have an odd creature to deal with—the boy. His mental outlook is quite different from that of the undergraduate and still more different from that of the mature man. You will not get anywhere with this youth unless you understand his mental outlook and adapt your course so as to fit in with it. The boy of 13 has got very little interest in the relations between facts, in which you and I are interested, but he has a veritable passion for information. So when we teach physics to boys, it is information that we have to give them.

They can absorb a staggering amount of it. Their memories are far better than ours.

Here is the second principle that I have tried to follow, and I think there is a good deal of evidence in favour of it. It is a biological fact that the development of the embryo reproduces the development of the animal kingdom, and it is my experience that the boy as he grows up to manhood reproduces the emotional and psychological development of the human race down the ages. If that principle is true, it follows that when we are teaching at this stage, between the ages of 11 and 16, we should teach the subject-matter as it developed historically. Teaching historically does not consist of stories about Newton and the apple, or stories about Faraday and how he was born at Clapham, belonged to some rather esoteric religious sect and then lived in Camberwell. Suppose we are teaching electro-magnetic induction. Teaching it historically means that we start with the ideas that made Faraday try his original experiments. You know far better than I do what they were. When you put a magnet near a piece of iron it becomes an induced magnet. Faraday hoped that, by analogy, if you put a circuit with a current in it near another circuit you would get a continuous current. He didn't, but he was a genius, and he followed up the momentary current he did get and arrived at the laws of electro-magnetic induction. Treat the subject as it, in fact, developed historically and we shall be in harmony with the boy's emotional and psychological outlook and he will respond and be interested. It is always an inspiration to me how year after year as I teach a subject in that way, the class can often anticipate steps that were, in fact, taken by the original investigators.

When I teach a class the thermometer, I try to do it this way. Of course, it is not easy because they have seen thermometers and they have some idea of what temperature means. I ask the class : " Can you suggest how to make a machine to measure temperature in numbers ? " You may have to suggest that you should have a bulb with a tube on the end of it with some water in it and the higher the water goes up the tube the greater is the temperature ; but they will quickly understand this. You will say : " What are the disadvantages of this thermometer ? " Somebody will tell you the water will evaporate. Then you close the tube, they say. What will happen then ? The air will be compressed at high temperatures and spoil the readings. Then you expel the air. The class will see for itself with little or no prompting the stages by which the present mercury thermometer was arrived at. That is education. It is the process of self-development. The boy is feeling out for the new ideas and gets joy and satisfaction in understanding how a good thermometer was

produced and how the problems met with in its design were overcome.

The third principle is that we should try to give the boy a knowledge of some of the important, fundamental generalizations of physics. The first such generalization is the laws of mechanics. It is fascinating for a boy to realize that force is not needed to maintain motion, as so many people think and as Aristotle thought. Motion will maintain itself if there is no force at all. There is an easy experiment that they can do. I did it with a sixth form arts students class six weeks ago. I wanted to convince them that a body could maintain the same speed without force. I told them that when they were going home in the train that night and when the train had got up speed they should take out a penny and drop it on the floor of the train, and the penny would go straight down. The train would be going at about 40 m.p.h. and although they let go of the penny it maintained its speed of 40 m.p.h. perfectly well. They have learned something when they have understood that.

Other generalizations to be taught are elementary principles in heat, in light—obviously one should try to do a little wave motion with them as they are all familiar with wireless waves. Sound is a good subject for this stage, and some of the principles of electricity. Here is one that I have very much in mind. How many ordinary persons think that the Battersea Power station makes electricity ? If we turn out educated young men, they will know that there is no electricity manufactured there, but that the energy of the coal or oil used is turned into electrical energy the value of which lies in the ease with which it can be distributed. Let us " debunk " the idea that science is a magical thing and that you build these factories and they produce energy out of nothing. Let them grasp the truth that energy cannot be created or destroyed, but only transformed from one kind into another.

There will have to be a good deal of practical applications of physics in the course, because it is a fundamental principle in education to proceed from the known to the unknown, and the practical applications are known to the boys. Practical applications are also in harmony with the boy's emotional outlook. He is interested more in information and how things work than in general principles. Although it may not appeal very much to the teacher personally, he will have to put in a good deal of practical applications of physics to capture the boy's interest.

Finally we must do the conservation of energy. That is at the root of the whole of our industrial revolution, and the boys must know that. How many people think now because atomic energy has been discovered that we can all sit back and do nothing. It is true that the new source of energy is very large compared with the supplies of

energy hitherto available, but the conservation of energy still applies ; the supply of atomic energy is not infinite.

All the time in teaching these generalization in physics and finishing with that supreme generalization, the conservation of energy, we must tell the boys explicitly and try to teach them implicitly what the aim and method of science is. I claim that every boy and girl who leaves a public or grammar school should have some little understanding of the aim and method of science. I want the boy to know and appreciate that the scientist is interested in collecting facts, in relating facts by laws, and that logical deductions from these laws suggest the discovery of new facts. I want him to see how this very powerful tool for obtaining new knowledge with fact and theory going hand in hand is so much more powerful for winning new truth than the old method of trial and error, which may have more " error " than anything else about it.

There, then, are the principles, and there are some of the aims. The boy will not know much at the end of it, and he will forget most of it in 10 years, but if he appreciates and understands what sort of a person a scientist is, what sort of problems he can solve and how he can solve them, that he must have laboratories and so forth to do it, then when the Minister of Supply says in the House of Commons that he wants to spend £100,000,000 on atomic research establishments, he has some idea of what these establishments can and cannot do and so can cast his vote at an election more intelligently.

Here are some practical examples of this presentation of physics in the school curriculum. I should like to begin with the simple machine. I think this is a good example of starting with concrete facts and leading to abstract ideas and so teaching scientific method. Many elementary books on physics make this mistake in explaining the simple machine. They start with the concept of work and say that work is done when a force acts on a body and moves it, and they give examples and define the efficiency of a machine as the output of work over the input of work.

It is quite easy to state what work is and to establish in your class a conditioned reflex so that when you mention the word " work " they will write out : " It is done when a force acts on a body and moves it." But that is not the point. The point is to convince them that this abstract quantity " work " is an important and fundamental quantity which controls the working of all machines ultimately, using the word " machine " in the widest sense.

How did the human race come across this abstract quantity " work " ? When I first taught by the method of the above text-books with the weaker forms, I asked them to work out the efficiency

of a machine, and they would give me the input of work over the output of work, and it would come to more than 1, and they did not see anything ridiculous about it. I wondered what was going wrong here. I said : " If you had a typist, how would you measure the efficiency of the typist ? " They said " Give her 100 words to type, and if she typed 95 correctly, the efficiency would be 95 per cent." They had the idea all right. What was going wrong was that they did not understand the concept of work ; the whole thing was meaningless to them and they were having to learn it and the definition of efficiency by heart. Because they did not understand it they could not apply it correctly. Also they said " Why cannot we define the efficiency of the machine as the mechanical advantage divided by the velocity ratio ? "

I was shocked, and then I began to think about it and began to approach the subject in quite a different way. What is the point of a machine ? They see that clearly—to get a big force out of a little one. If you ask an ordinary class what is a good way of measuring that in numbers it will not be long before they tell you that it is the load over the effort. I said : " You think you have something good here." I told them a story of a farmer who had a warehouse and wanted to lift his sacks of corn from street level to the top floor, a distance of 50 ft. The sacks weighed 200 lb., and he had to use four or five men to pull them up. A commercial traveller came along with a machine and said : " With this machine you will need only one man to pull up the sacks." The machine had a mechanical advantage of 10 and could lift the sack with a force of 20 lb. The farmer fell for it and bought the machine. But there was a disadvantage ; if you tried to raise the sack through 50 feet using the machine you had to pull in 750 ft. of rope. I said to the class : " There you are. There is the commercial traveller. He has sold the farmer a machine with an advantage of 10 : 1, but the disadvantage is 15 : 1."

I then said that another commercial traveller came along and offered the farmer another machine with a mechanical advantage of 5, and the velocity ratio in this case was 7, so that he needed to pull in only 350 ft. of rope. I said : " How will the farmer tell which is the better of the two machines ? "

The farmer, a good church-goer, consulted the vicar, who was a cultured man. The vicar thought about it and said : " Here is one machine with an advantage of 10 but a disadvantage of 15. There is another with an advantage of 5 but a disadvantage of 7." Some horse-sense was needed. You might say that you had to make up your mind whether $\frac{2}{3}$ was better than $\frac{10}{15}$. The vicar was intelligent, and he looked at the machine and said : " There is a certain amount

of waste in these machines ; you waste effort both in raising the bottom block of pulleys and against friction of the pulleys." He realized that the way to decide which was the better machine is to compare their performance with that of perfect machine, which could be calculated, although it could never be made. He invented in his own mind a perfect machine, with a bottom block of pulleys with no weight and no friction, and he found that in the case of the perfect machine the mechanical advantage was just equal to the velocity ratio. He said : " Here is your answer. If commercial travellers offer you a machine in which the mechanical advantage is equal to the velocity of ratio you will buy it." That is the performance of a perfectly efficient machine. If the machine has not that performance, it is an inefficient machine. Then you have a good definition of efficiency : the efficiency of a machine equals the mechanical advantage of your actual machine divided by the mechanical advantage of a perfect machine of the same design, that is, efficiency is mechanical advantage divided by velocity ratio. So you see that this is just like the case of the typist. A perfect typist will type 100 words correctly out of 100. An imperfect typist will type only 95 words correctly. The farmer can now tell which of his two machines is the better.

I found that the weaker boys had no difficulty in solving problems about the efficiency of machines if it was treated this way, because they were dealing with concrete quantities like force and distance.

Then the vicar said—he did not bother the farmer with it ; he bothered himself with it—" Why is it that nature seems to put this curse on us that she will not let us have a machine in which the mechanical advantage is bigger than the velocity of ratio ? Why is it that in the perfect machine they are only equal ? " From the equation expressing that mechanical advantage equals velocity ratio, we quickly get an equation to show that output of work equals input of work. I suggest to you—I do not know whether it is historically correct or whether we can ever find out—that is how the concept of work was arrived at and, in the same step, the principle of work. Work is the significant quantity. Once you have the expression for it you can see its significance. You expect the machine to exert a force on a body and move it, and the product of the two shows you how much the machine has done. It is the same as the conception of man-hours, measuring the amount of work put into a factory in a week, the product of all the number of men working and the number of hours each has worked in the week.

So the vicar concluded with this principle. Machines will not operate unless they have a supply of work. The best machine will give you just as much as you put in, but no more. An imperfect machine

wastes some work and so the output of work is less than the input. That is why the mechanical advantage is less than the velocity ratio in an imperfect machine. The vicar then realized that he knew why a perpetual motion machine would not work. In the 15th and 16th centuries the human race tried incessantly to make such machines. You start talking to boys about perpetual motion machines and they will listen to you for hours and read about it for hours. Why ? Because at the age of about 15 they are in the same state of mind as the human race was in the 15th or 16th century. They really think that they can invent a perpetual motion machine. Let them get on with it ; they have to go through that stage. In due course they will realize like the vicar that a perpetual motion machine cannot work because its output of work would be greater than the input of work, which is impossible.

If we teach the subject that way, the boys can understand what we are talking about, and they understand how the human race got at the conception of work and its fundamental importance. They understand the conservation of energy. That is what I mean by teaching science to the future citizen as it did in fact develop historically. You will have to supplement this by emphasizing that what the scientist is doing is collecting facts and trying to find a relation between facts, but as well as telling them this you have to make sure that they do some of it themselves, as that is the only way they can appreciate scientific method.

When I taught elementary magnetism to beginners, I gave them four experiments to do in the laboratory. I gave them a magnet and told them to dip it in iron filings, take it out and study what happened. I gave them a magnet and put a piece of iron in a stirrup and told them to offer each end of the magnet to the iron and record what happened. I told them to hang a magnet in a stirrup and see what it did. I told them to offer each end of the magnet to each end of another magnet in the stirrup. I did not tell them what they would get.

When they had finished I went through each point with them in the lecture room. I would say, " What did you get ? " If there was any doubt about what they got, I repeated the experiment in front of them. I said, " The truth is not what I say and not what a particular text-book says. The truth is what happens, and you and I have to get the same result every time before it is a fact."

When we had established that—I suggest to you that it takes 1½ or two hours to do—they had learned something about magnets and about scientific method.

I then went on to magnetic induction and told them to put a magnet near a piece of iron and study the induced poles. If there was any

disagreement, we did the experiment in the lecture room, demonstrating the polarity induced at each end of the iron.

A very interesting point arose once in the course of that lesson. It arose several times before I spotted what there was in it. In doing magnetic induction in front of the boys, I did this simple experiment. I put a magnet near a piece of soft iron and dipped the iron into a bowl of iron filings. I sometimes used to touch the soft iron with the magnet, and one day a boy said, " You are cheating. You are touching the iron with the magnet. That is not magnetic induction. You should set up the magnet near the iron." I said, " What does it matter if I touch it ? " The boy said, " If you touch it the magnetism flows from the magnet into the iron." I said, " What do you think magnetism is ?" The boy said, "A sort of fluid. You were trying to exert its influence through space." I said, " You say that it is a fluid and that it will flow into the iron and is not being exerted through space. If that is true, if magnetism is a fluid and flows from the magnet to the iron can you suggest an experiment to see if your idea is right or wrong." Sometimes a boy will see that the magnet would get weaker if this was happening and I would suggest a simple experiment to test this and we saw that the suggestion was wrong. But the boy was really being educated. His mind had formed this idea. I had never put it into his head that magnetism was a fluid, but he had thought of it, and he had a definite idea of what the experiment was about.

Ever after that when I was doing magnetic induction I asked the class what they thought magnetism was. One year I got a shock. A boy said " I think the magnet has a lot of little magnets in it." I asked him to come to the board and explain his ideas. He gave a good exposition of the very elementary molecular theory of magnetism. The boy was not very clever in the academic sense, but he gave quite a good little account, and he drew on the board not closed chains but little magnets pointing in random directions and described how you made a piece of iron into a magnet. I asked him if he had read it in a book. He said " No." However, I wondered whether he had read it two or three years before and the idea had just come back to him. Anyway, he was interested enough to think. It all illustrates the point that if you treat a subject as it developed historically you will then find the class going ahead of you following the path that the human race originally trod.

One hot summer's afternoon I was teaching a class making magnets, and I put a piece of iron, which I had shown them was not a magnet, into a solenoid and passed an electric current through the solenoid and then took the iron out and it was magnetized. The experiment worked well. It was a hot stuffy afternoon, and I was a bit tired. A boy in

the front row said, " If you put a magnet into that coil, would you get an electric current ? " I was a bit irritated and thought " That is a silly question to ask," when it occurred to me that this was one of the ideas that led Faraday to the discovery of electro-magnetic induction. So I said " Why do you think you should get a current there ? " He replied " The electric current produced a magnet ; I wondered if a magnet could produce an electric current." So the boy's mind was working on the same lines as those on which the great physicist's mind was working 100 years ago.

May I mention one or two other points. I talked about the subject-matter of a course of physics and said that we should try to start with something with which the boys are familiar, if possible. I am very fortunate in that although I have been a headmaster for 15 years I have been at schools where it has been possible for me to continue to teach physics, some in the middle school and some in the sixth form. When I first went to the City of London School I taught physics in the fourth form for two periods a week. The form was doing mainly classics and mathematics and it was a very good form. I chose to do Sound, and during that year the form made such good progress that I decided to include the Doppler effect. Strangely enough, when I started doing pitch, loudness and quality, one boy asked me if pitch was the sort of queer change that you get when an aeroplane passes. He had notice the Doppler effect. I taught the Doppler effect this way. I did not give them any algebraic formulae. I contented myself with giving them the qualitative facts. They had all already noticed the effect. One boy said " You can here this at Clapham Junction station. There is a bell there which rings as trains go through, and if you go through without stopping you hear the pitch of the bell dropping." Other boys had noticed a similar effect with the whirring of a motor car passing an observer either standing by the road or going in the opposite direction in another car.

When we got the qualitative facts established, I gave them some simple numerical examples of the change in pitch, first of all with the stationary observer and the moving source, and then with both moving.

I did the work in the Lent term. There was an examination at the end of the Summer term, and in that examination I deliberately put in a question on the Doppler effect, including a quantitative calculation. In that quantitative calculation I made use of a plain straightforward example of the type I have mentioned—we had done several in class—of a person standing on a platform and a train coming towards him at a certain speed. They had to work out the pitch of the whistle as the train approached and receded. Then they had to do it in the case of a person standing on the platform the next day when there was a wind of 15 m.p.h. I had never said a word to them about winds. Six boys

in the class of 30 got this last part of the example right and quite clearly understood what they were doing.

This example shows how much boys can learn if the subject is suitably presented to them. I deliberately kept them off algebra, because in learning there is also the conservation of mental energy. A child is capable of a certain amount of mental output of energy when tackling a problem. The output of mental energy of this form was only big enough to learn the new ideas underlying the Doppler effect ; they had no mental energy left for understanding even the simple algebra of the usual treatment. So I did the quantitative work in simple arithmetic and left all their mental energy for understanding the physical principles involved.

The only thing I would say about advanced physics in the sixth form is this. We are laying the foundations of a course of physics in the sixth form. So we should try to implant in these boys the research attitude. It is the same principle as teaching them the subject as it, in fact, developed historically. In teaching them the elementary facts about light, if you are intellectually honest, you will give them the material corpuscular theory and the wave theory. I have heard a boy say, while being taught optics in this way : " I am in a fog," and I replied " I am glad you are. The physicists at the end of the 17th century were in a fog. We must see how to get out of it. If you go into industrial research you will get into a fog when you have problems to solve and if you don't know how to get out of it you will get the sack."

At the university you have to cover the same ground but this need not mean that the students are bored ; take light for example. If I were teaching optics at the university I should start with the equation of wave motion and deduce the various properties of waves mathematically, and as I came to each property I should give its experimental verification. So often we are told that boys have learned too much at school and are bored when they cover the same ground at the university. I suggest that that is because the universities are not teaching as well as they should teach. If we do optics at school in the way I described above and, when the boy's logical faculty is more developed, the same ground is covered at the university, starting with the equation of wave motion, it will not seem the same ground to the students because it will be treated in a different way and in a way which will appeal to their mature and more developed logical faculty. There is bound to be some common ground between school and university, but there should be more co-operation in deciding the most fruitful way of dealing with it.

I am convinced that physics—I would say this to an audience of chemists, too—with Greek is the finest mental discipline that there is

to be found in our school curriculum. Physics is a better discipline than either mathematics or chemistry, for this reason. The mathematician can succeed with one faculty only—logic. It does not matter whether he understands about facts, because they are of no interest to the mathematician. He has just got to have an extremely good logical faculty. The chemist can succeed if he has a good memory for facts. But the physicist must have both logical faculty and the ability to appreciate facts and to evaluate them so that he can induce the general principles which will make sense of them. The student of Greek needs the same two qualities ; an acute logical faculty to understand the grammar and syntax and the power to apprehend the general experience of reality, which are so beautifully and clearly expounded in Greek literature and philosophy. There is then no question that physics must have an honourable place not only in the curriculum of the Science specialist but in the liberal general education which should constitute the basis of any good secondary education.

YORKSHIRE BRANCH DISCUSSION ON TRAINING FOR INDUSTRY

PROFESSOR W. SUCKSMITH (*Fellow*) was the chairman at a conference on " The Training of Physicists for Industry " held at the College of Technology, Rotherham, under the auspices of the Yorkshire Branch of the Institute, on the 21st April, 1955. After thanking the Principal of the College, Mr. G. E. Cooke, for his hospitality and words of welcome, he said a year ago when a similar conference was held in Bradford it was clear that a large gap existed between the demand and potential supply of physicists. Ministerial announcements of development in both the peaceful and military aspects of nuclear energy would widen this gap.

DR. K. W. ANDREWS (*Fellow*), Research and Development Department, United Steel Companies Limited, pointed out that there is no physical industry but a need for physicists in many industries ; the education of a physicist is a continuing process which does not cease until death or retirement. The university graduate entering industry should have a wide cultural outlook and an interest in people and affairs, but will be put under the obligation to gain much further knowledge about the technology of the industry for which he works. The student coming up the " hard way " may not have delved so far into the fundamentals of modern physics and will also need to gain something of the cultural outlook. On the other hand he may be more familiar with some aspects of the technology of his particular industry. Ultimately his outlook ought not to be so very different. Both will find the need for further study possibly by special advanced courses, summer schools, etc., and at least by further reading.

It is necessary to be something of a physicist in order to be many other kinds of scientist or engineer. It is also necessary to be something of a mathematician in order to be a physicist. The mathematical element in physics frightens some people ; probably they do not reach their " mathematical ceiling " because there has been no one to help them through their particular difficulties. Serious attention should be given to the techniques of presentation rather than the content of mathematical courses.

MR. E. BOARDMAN (*Associate*), Senior Physics Master, The Grammar School, Doncaster, said that two teaching difficulties in schools were the inadequate command of mathematics, and the lack of manual dexterity of many pupils. He felt that more time should be given to handicrafts, that laboratories should be far better equipped with tools and work bench space, and that in mathematics greater attention should be given to graphical work, relative error and approximation.

Interest in physics in sixth forms he thought had increased, following the introduction of the Joint Matriculation Board's modified Advanced level syllabus which encouraged the study of more topics dealing with recent advances in physical science.

MR. B. BRADLEY (*Associate*), Senior Lecturer in Physics, College of Technology, Rotherham, explained that most of the physics taught in the College is subsidiary to other subjects. For those really being trained as physicists for industry there are two options. In the past many have taken the London University General B.Sc. degree. New regulations will make this degree more difficult to obtain. Rotherham was the second Technical College to organize courses for the National Certificate in Applied Physics. Pure and applied physics are taught together up to the Ordinary standard. Courses in applied physics for the Higher National have included temperature measurement and control, advanced magnetic and electrical measurements, statistics, spectrographic analysis, high vacua and electronics. At the moment the College is concentrating on the last two subjects, but others could be revived if the demand arose.

The number of candidates offering themselves for the applied physics courses is unsatisfactorily low. The local industry being mainly steel making, most students take metallurgy, chemistry or engineering. The opportunities in physics are not sufficiently well-known especially in the Grammar Schools.

He was forced to the conclusion that the standard of the Higher National Certificate could be reduced with advantage in mathematics. (At present it is about the same as the General B.Sc.) Students can pass the physics with comparative ease but in mathematics are loaded

beyond the yield point. We are trying to produce high grade technicians not mathematical physicists. Instead of the second year mathematics more pure and applied physics could be done.

Mr. Bradley concluded by describing a successful Physics in Industry course and with a plea for more articles of use to teachers of physics in the Institute's journals.

DR. HOARE (*Fellow*), Reader in Physics, University of Leeds, stated that universities cannot train physicists for industry or any other specific occupation. The teaching of physics in universities cannot be considered separately from that in schools where the foundation is laid. The school course is not intended as the first part of a specialist course in physics, and the broadly based course aiming at a wide factual knowledge is frequently advocated. He considered an introduction to scientific method obtained by a thorough understanding of a limited range of facts more important. At the university co-operation between the lecturers dealing with different sections of the subjects is necessary, but not always easy to achieve. At Leeds much of the first year is occupied by a course entitled " Atomic and molecular physics " given by one person. Although the more difficult mathematics is left until later, the interpretative side of the subject is stressed and numerical examples are worked. Terms and concepts are introduced naturally. Physicists trained to examine carefully the foundations of the subject will meet more successfully the challenge of industrial problems.

In the discussion which followed Principal G. E. Cooke emphasized that National Certificates were intended for technicians and should not be too closely tied to professional qualifications. Mr. M. L. Meyer described the work of so-called postgraduate schools at the University. A degree was not necessary ; five week intensive courses were provided for people working in industry.

Several speakers pointed out the difficulty which undue specialization with too many options in schools could cause the university teacher. Others dealt with the mathematics syllabus for Higher National Certificate. Apart from the question of difficulty there were pleas for more concentration on practical aspects. Mr. D. B. Edwards of Rotherham Technical College quoted an example in which the assessor had replaced a question on theory of errors by one on partial differential equations. There were several suggestions for more co-operation and contacts between schools, colleges and industries.

M. McCAIG.

[*The Institute's assessor for mathematics in the National Certificate examinations makes the following comments on the remarks concerning the*

standard of the mathematics demanded for the Higher National Certificate in Applied Physics.

The statement that the standard of the Higher National Certificate Mathematics is at present about the same as that of the B.Sc. General degree merits some qualification ; the latter covers a much wider field and the examination is more searching, for there are three papers as against one in the Higher National Certificate examination. (Under the new regulations the difference will be even wider.) I doubt if many who pass the Higher National Certificate examination would be successful in the B.Sc. General examination ; fewer still would pass in mathematics in the Graduateship examination.

One can only regret that at one College " the students can pass the physics with comparative ease but in mathematics are loaded beyond the yield point," for this is certainly not true of the Higher National Certificate examinations as a whole. Indeed there is a close correlation between failure in mathematics and failure in physics. Moreover, there is no evidence at all that we are breeding a race of mathematical physicists.

Mr. D. B. Edwards probably now agrees that the assessor was right to remove from an A.2 (Higher National Certificate) examination a question on the theory of errors which was worthy of an S.3 (Ordinary National Certificate) paper ; it was replaced by a question on partial differentiation—*not* partial differential equations—taken from physics. The assessor does not claim infallibility, but he does try to maintain some uniformity of standard amongst the various Colleges.

The teaching of mathematics is too important for us to lose ourselves in criticisms of details of examination papers. We should do well to address ourselves to more fundamental questions. Are we teaching the subject as it should be taught to physicists ? Have we, guided by the experience of the past few years, proposed changes in the syllabuses ? Are we worrying too much about the standards achieved in certain techniques, and neglecting the more important question as to whether the students are able to translate physical situations into mathematics and to interpret mathematical equations in physical terms ? We should do well, I feel, to read again and ponder the Institute's Report, *The Teaching of Mathematics to Physicists.*

It may be that generally we are attempting to crowd too much into the two years of the Higher National Certificate course ; if we are, let us be careful about putting in more physics at the expense of the mathematics.]

REVIEWS OF BOOKS

Relativity for the Layman. By JAMES A. COLMAN. (New York : William-Frederick Press.) Pp. 131. Price $2.75.

There seems no end to popular books on relativity in spite of the difficulties the layman must have in trying to understand them. One often wonders who are the laymen who read these books and what they make of them. And yet it is widely recognized that there is a vital need in this specialist age to make the results of science and its method available in a form suitable for those trained in other disciplines. The author thinks, rather optimistically, that relativity is difficult to understand " only because its predictions are difficult to believe—not because of any innate incomprehensibility."

This book is not for everyone ; it will perhaps be of most help to scientists with little or no knowledge of physics, or even to those physicists who would appreciate a descriptive account, without mathematics, of the essential ideas of the theory which we owe to Einstein. Other readers will not find elsewhere a more lucid, reliable and interesting short account of the history of the main developments in physics which led to the Special Theory of Relativity in 1905. This first part of the book is excellently done ; only occasionally does the inevitable compression seem misleading, as for example on p. 52 where it seems to be implied that the neutron was discovered earlier than it was.

The rest of the book dealing with the general theory and the three crucial tests, with relativistic cosmology and with unified field theory—all in forty short pages—is not so successful. Perhaps it attempts the impossible. But the author's enthusiasm is maintained to the very end; his final sentence " We await the future with bated breath " will mean different things to different readers.

J. TOPPING.

Science and Christian Belief. By C. A. COULSON, F.R.S. (London : Geoffrey Cumberlege, Oxford University Press.) Pp. 118. Price 8s. 6d.

This book comprises the John Calvin McNair Lectures delivered at the University of North Carolina in 1954. It is a little volume that I find difficult to review without giving the impression of extravagance ; this is the last thing that I should wish, for every page bears upon it a stamp of integrity and a careful regard for the limit of validity of any argument adduced that are rare in works of this kind. Although the lectures are beautifully written in a lucid style, with a fascinating

infusion of apt quotation, Professor Coulson has shown the virtue that C. P. Scott so much admired, of " holding himself in," and throughout seems clearly conscious of the power of his case presented in simple terms. As Eddington said, " there is a kind of sureness which is very different from cocksureness " ; Professor Coulson has displayed it admirably and should appeal especially to scientists.

There are four chapters. The first two may be summarized in Professor Coulson's own words: " In our first chapter I showed that if God is to be found in science at all, it must be as an absolutely integral part of it. There was no hope for any scheme which tried to fit Him in between the gaps left over after science had first claimed its possessions. In the next chapter I showed how this could be, since science was an essentially religious activity, characterized by much the same temper and spirit as religion. It was possible to make the claim that science was one aspect of the revelation of God." His third chapter, " The Human Element " discusses the extent to which science consists of conceptual patterns constructed by us to rationalize our (scientific) experience. The final chapter is on " Christian Belief."

As he indicates in the preface, Professor Coulson has used some of the argument, notably the repudiation of a " God of the gaps," that he has already given in his Riddell Memorial Lectures, *Christianity in an Age of Science* (1953), but by comparison with the present volume the Riddell Lectures are, in my opinion, quite pedestrian.

It is perhaps arguable whether Professor Coulson ought to have chosen the title that he has. " Science and the religious view of life " would have been a more accurate, if less attractive, title. The book runs to less than 120 pages but at the bottom of page 102 Professor Coulson says of his argument so far—" It is true that this has not got us to the Christian faith. In one sense it has only got us as far as pantheism." For the development from pantheism to Christianity there remain only sixteen pages and it is not surprising that this seemed to be the least satisfying part of the book. A more adequate discussion of specifically Christian beliefs would have made the book more rounded and more valuable still.

Professor Coulson is known to physicists as one of the most distinguished of present day theoreticians. To non-scientists this little book may well serve as a revelation that some of the most profound scientific thinkers bring an attitude of reverence to their work and from it gain an enhanced intensity of religious purpose. Of religious truth no less than of scientific truth, Professor Coulson can say, with George Fox—" and this I knew experimentally."

NORMAN CLARKE.

Introduction to Theoretical Mechanics. By Robert A. Becker. (London : McGraw-Hill Publishing Company Ltd.) Pp. xiii + 420. Price 57s. 6d.

This book by the Associate Professor of Physics in the University of Illinois has as its basis a course of lectures delivered to undergraduates in engineering physics and also attended by many physics students. The introductory chapter is concerned with the elements of vector analysis and the laws of motion and then the book ranges through the statics of particles, rigid bodies and flexible chains, the principle of virtual work and the stability of equilibrium through the dynamics of a single particle, of a system of particles, of a rigid body moving in a plane and in three dimensions, to generalized co-ordinates, vibrating systems and wave motion.

I think there is much in this book that students will find useful, particularly the later developments. My criticism centres round three points. Firstly, the treatment of the laws of motion and in particular the definition of mass and force which I felt to be confusing. Secondly, in the determination of the equations of motion of a rigid body, the assumption is made that interaction between neighbouring particles is " central " (i.e. in the line joining the particles). Thirdly, statics is treated before dynamics but only by referring the reader forward to the appropriate dynamical section for the equations of equilibrium. The third point may be dismissed as a matter of taste but the other two are more fundamental and particularly in a book of this nature for physics students I would have expected a more careful treatment.

One essential requirement of a book of this nature is that it should have a large supply of examples both worked and set and this requirement is amply fulfilled. It can certainly be recommended as supplying valuable additional reading.

L. HOWARTH.

Applied Electronics, Second Edition. By TRUMAN S. GRAY. (New York : John Wiley and Sons, Inc. London : Chapman and Hall Ltd.) Pp. xxviii + 880. Price 72s.

The faults of most text books on electronics are that they are too long in relation to the useful information they contain, and that the basic physics of the electronic devices is inadequately treated. The first criticism cannot be levelled against Professor Gray's revised edition of a work first published in 1943, and the edition will be welcomed not only by the student, for whom it is primarily intended, but also as a reference book for the engineer practising in the field of electronics. After reading in the preface " This book is for a first basic course. Rigour of thought and analysis rather than extensiveness

of scope is its intended feature," one is, however, a little disappointed to find some instances of a lack of rigour which has been characteristic of most of the text books so far published. In the chapters devoted to vacuum tubes, for example, the effect of space charge is ignored in the analysis of tube characteristics and the intelligent student may well be puzzled by an analysis which includes a charge Q_k on the cathode when he has already been told earlier that under operating conditions the field at the cathode is zero. Again, in the discussion of beam power tubes the phenomena that occur in the neighbourhood of the knee of the curves are lightly dismissed as " somewhat complex." A simple physical explanation would surely have been helpful in illustrating the fundamental physical principles involved.

In spite of these criticisms, however, Professor Gray's book is one of the best that have yet been published. The first introductory chapters on electron ballistics, emission, and conduction through vacuum and gases, are excellent introduction to the succeeding sections on tubes and tube characteristics. The student is introduced to the basic physical concepts before being given the more formal mathematical treatment of the phenomena. In the sections on circuits, rectifiers, amplifiers and oscillators, etc., the subjects are treated with considerable thoroughness, although " noise " merits more consideration than is given in the few pages devoted to this important factor. There is a useful concluding chapter on semi-conductors and transistors.

There are numerous references to original papers and a useful classified bibliography at the end of the book. Each chapter is followed by a well selected set of questions designed to test a student's knowledge of basic phenomena and applications.

G. W. WARREN.

The following reports have also been received :—

Modernisation and re-equipment of British Railways. (*London : British Transport Commission.*) Pp. 36.

The British Coal Utilisation Research Association. Annual Report for 1954. Pp. 68.

University of London. University College Annual Report for 1953-54. Pp. 97.

The Year Book of the International Council of Scientific Unions, 1955. Pp. 69. Price 5s.

NEWS OF MEMBERS

Honours List

The names of the following Fellows of the Institute were included in the Queen's Birthday Honours List.

C.B.E. : DR. A. B. D. CASSIE
DR. J. V. DUNWORTH
DR. G. E. FOXWELL

Fellows

SIR JOHN COCKCROFT (*President*) has received the honorary degree of Doctor of Laws from the University of St. Andrews.

DR. J. N. ALDINGTON, Managing Director of Siemens Electric Lamps and Supplies Limited and of Alfred Graham and Company Ltd., has joined the Board of Siemens Brothers and Company Ltd.

DR. K. A. G. MENDELSSOHN has been appointed Reader in Physics in the University of Oxford.

DR. W. SARAGA was one of the joint authors of the paper which has been awarded the Clerk Maxwell Premium of the British Institution of Radio Engineers as the most outstanding paper of the Institution's Journal of 1953.

Associates

DR. R. G. ALLEN is shortly to take up the post of the first Director of Research of the Water Research Association.

DR. S. H. AYLIFFE has been appointed Head of the Department of Physics and Mathematics, College of Technology, Bristol.

P. G. E. F. JONES is now a Senior Scientific Officer at the Atomic Weapons Research Establishment, Aldermaston.

M. THOMAS is now with Shell-Mex and B.P. Ltd.

J. S. THORP has taken up an appointment with the Radar Research Establishment, Worcestershire.

Graduates

D. A. CALDER is now Assistant Lecturer in Physics at the North Staffordshire Technical College.

K. J. CLOSE has been appointed Assistant Lecturer in Physics at Nottingham and District Technical College.

C. R. COLEMAN is now a Physicist at the Dunlop Research Centre, Birmingham.

MRS. A. E. GRAY (formerly Miss. M. I. McG. Leckie) is a Research Physicist with the British Scientific Instrument Research Association, Kent.

R. PIGG has changed his surname to Gordon.

LONDON AND HOME COUNTIES BRANCH
SUMMER MEETING

On Saturday, 4th June, a party of over 100 members of the Branch and their friends visited the National Institute of Oceanography at Wormley, near Godalming, Surrey. The National Institute of Oceanography is responsible for various branches of research work formerly undertaken by the Admiralty, together with the "Discovery Investigations" including operation of the Royal Research Ship Discovery II.

On arrival the party was welcomed by the Director, Dr. G. E. R. Deacon, C.B.E., F.R.S., after which the visitors were free to tour the establishment and examine equipment and exhibits associated with various aspects of marine physics and marine biology. A film show illustrating the work of the Royal Research Ship Discovery II was included in the programme. During the tea interval the Branch Chairman, Dr. J. S. Forrest, thanked Dr. Deacon and his staff for their hospitality and in particular for specially opening their laboratories on Saturday for the benefit of Branch members.

B. S. COOPER.

Some members of the London Branch Committee :—[Left to right : Mr. B. S. Cooper (Branch Honorary Secretary), Dr. D. H. Follett, Dr. R. Jackson, Dr. J. S. Forrest (Branch Chairman), Mr. T. Somerville and Professor A. M. Taylor]. A photograph taken at Wormley.

A vacancy exists for an **X-ray crystallographer** to work as a member of a new and expanding group engaged in investigating fundamental behaviour and properties of alloys. The work initially involves the application of special X-ray techniques to the study of pre-precipitation phenomena. Some research experience is required but need not necessarily be in the particular field outlined above. The work is interesting and progressive, and provides an unusual opportunity for a man with initiative and enthusiasm to perform original research, which may be suitable for publication. The laboratories are situated in pleasant country surroundings and have recently been extended. The salary will be attractive and in accordance with age and experience. A pension scheme is in operation. Applications should be addressed to the Director of Research, **Aluminium Laboratories Limited,** Banbury, Oxon.

A **metallurgist** is required for investigation of problems in the field of physical metallurgy, including a basic study of diffusion, or of certain aspects of recrystallization behaviour. It is anticipated that the results may be suitable for publication. The vacancy would suit a recent graduate (one or two years' industrial experience would be an advantage but is not essential). A pension scheme is in operation. Applications should be addressed to the Director of Research, **Aluminium Laboratories Limited,** Banbury, Oxon.

Two vacancies exist in a team working on the casting of aluminium alloys. A long term programme of work is in progress covering a study of the semi-continuous casting process, in particular on problems involved in temperature distribution, thermal transfer, and the influence of these factors on metallurgical structure. Techniques for rapid temperature measurement, use of electrical analogies, and for the use of radio active tracers may interest applicants. The vacancies would suit recent graduates but a few years' industrial or research experience would be a distinct advantage. A pension scheme is in operation. Applications should be addressed to the Director of Research, **Aluminium Laboratories Limited,** Banbury, Oxon.

The British Thomson-Houston Company Ltd., have a vacancy in their Research Laboratory at Rugby for a qualified **Physicist** or **Engineer** for radiation measurements in a lamp development group. The work is varied and interesting, and offers scope for development of new techniques.

Applicants are invited to send particulars of their age and qualifications to the Director of Research, British Thomson-Houston Co. Ltd., Rugby, quoting reference RM.

European Council for Nuclear Research, Geneva, has a number of vacancies for **research physicists, electrical, electronic** and **mechanical engineers** to assist in the design and construction of high energy accelerating machines for nuclear research. The posts, in varying grades, carry salaries ranging from 10,200 to 20,100 Swiss francs tax free per annum.

First class qualifications and experience essential. For further information and application forms write to the Secretary, Ministry of Labour and National Service, Almack House, 26 King Street, London, S.W.1, quoting A12/179/CERN.

Experimental Engineer. Markham and Company Limited invite applications for this position at their Works in Chesterfield. Applicants should have knowledge of and experience in applying the present day experimental stress analysis techniques. A background of experience in the Heavy Engineering Industries would be helpful. A good Superannuation scheme is available and assistance with housing can be given if necessary. Applicants should have completed their National Service and they should write giving their age, present occupation and brief details of their duties and responsibilities. They should also give concise details of education and past experience chronologically. Applications will be treated in the strictest confidence and should be addressed to The Secretary, Broad Oaks Works, Chesterfield.

Essex Education Committee

Mid-Essex Technical College and School of Art, Market Rd., Chelmsford. Required in September (preferably) or by January, 1956, **Lecturer** (man) to teach Physics to B.Sc. (General) Degree standard and Applied Physics to H.N.C. standard.

Candidates should be University Graduates with appropriate teaching and research/industrial experience. Corporate membership of The Institute of Physics desirable.

Salary scale, £965 by £25 to £1,065 per annum.

Details and forms (stamped addressed foolscap envelope) from Clerk to the Governors.

South-East Essex Technical College and School of Art

Longbridge Road, Dagenham

Applications invited for appointment as **Research Assistant** to carry out fundamental research in the field of X-ray production. Candidates should hold a good honours degree. Salary £350 per annum.

Details from Clerk to the Governors at the College.

Mechanical Engineer (or Physicist), with University Engineering Degree, required for senior position in Research and Development Department of Company in light precision engineering in Central London. Age about 34–44 : Research experience, knowledge of patents and languages desirable. Starting salary £1,200 to £2,000 per annum, according to qualifications. Non-contributory Pension Scheme available. Box AV. 81, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

The British Thomson-Houston Co. Ltd., require Graduate **Engineers** and **Physicists** for the design, construction and processing aspects of magnetron and other electronic valve developments. The work is carried out in close association with a small machine shop and pilot production unit, and every encouragement is given to the development of new ideas. It is work in which both practical and theoretical interests are desired. Applicants should write to the Director of Research, British Thomson-Houston Co. Ltd., Rugby, giving their age, qualifications and experience, and quote reference FT.

Bursary at £350–£400 p.a., plus fees, tenable in the Department of Chemical Engineering for research normally leading to Ph.D. Degree on the application of precision optical methods to problems of flame propagation in gases. Applications from graduates in physics, including those graduating this summer, to the Registrar, Imperial College, London, S.W.7.

(*Continued on page vi*)

The United Kingdom Atomic Energy Authority requires a university graduate for its Operations Planning Section at the Industrial Group Headquarters, Risley, Lancs., to lead a small team concerned with the technical policy of commissioning and operating the Reactors and Diffusion Plants being built by the Authority. The post will involve some travelling between the Authority's establishments. Candidates should be at least 28 years old and have a good Honours Degree in Physics or Applied Mathematics. An interest in economics would be an advantage. Initially opportunities will be provided to acquire familiarity with the specialized processes of Atomic Energy. The appointment offers a good career to applicants with first class qualities. Salary will be assessed on appointment within the scale, £1,425 – £1,620. All new entrants under the age of 55 automatically join the Authority's Contributory pension scheme. A house will be available within a reasonable period for the successful candidate, if married.

Suitably qualified persons are invited to send a postcard for Application Form to the Recruitment Officer, U.K.A.E.A., Industrial Group Headquarters, Risley, Nr. Warrington. quoting reference 1,011.

Engineers and Physicists.

Ferranti Limited in their new Laboratories are engaged in a programme of electronic development of great industrial importance. The work involves the use of digital computors to control machines and industrial processes and covers a wide and expanding field of application, offering long-term interest to those engaged in it.

Development activity for these projects is taking place in the field of electronic circuitry (including pulse technique), digital computers, magnetic recording and servomechanisms. Engineers and Physicists having experience as well as interest in one or more of these subjects are invited to apply.

The appointments are permanent and offer full scope for initiative in an expanding organization. A salary commensurate with the qualifications required will be paid. Staff pension scheme. Application form will be sent on request (quoting Ref. 40/EP/AL) to the Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh, 5.

University of the Witwatersrand, Johannesburg, South Africa

Applications are invited for the first appointment to the newly established post of **Professor of Experimental Physics.**

The substantive salary attached to the post is on the scale £1,650 × £50 – £1,950 per annum. In addition, a married man will receive cost of living allowance at such rate as may be authorized from time to time. The present rate of cost of living allowance is £234 per annum.

The medium of instruction at the University is English, and ability to speak and write English is essential.

The successful applicant will be required to assume duty on the 2nd January, 1956, or as soon as possible thereafter.

An allowance is made towards travelling expenses.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

The closing date for the receipt of applications, in South Africa and London, is 10th August, 1955.

MATHEMATICIAN

(Graduate)

is required for the solution of problems arising in new applications of diesel engine injection equipment.

The work involves the use and refinement of a digital computer programme.

National Service must be over.

Salary according to qualifications and experience.

Apply in writing to the
PERSONNEL MANAGER
C.A.V. LIMITED
Warple Way, Acton, W.3
quoting Ref. R.16.

The British Petroleum Company Limited requires for research and development in geophysics at its Research Station in Nottinghamshire, a **physicist** with honours degree and at least two years' post-graduate research experience. Some knowledge of electronics, particularly in its application to field instruments, is desirable. Salary according to age, experience and qualifications. Good Pension Scheme. Write, stating age and giving full details, quoting H.3337, to Box 7720, c/o 191 Gresham House, London, E.C.2.

The British Thomson-Houston Company Ltd., has a vacancy in its Research Laboratory at Rugby for a qualified **Electrical Engineer** or **Physicist** for work on radio interference problems. The work covers investigation of the mechanism, measurement and suppression of radio interference over a wide and interesting range of sources. Applicants should write to the Director of Research, British Thomson-Houston Company Ltd., Rugby, giving their age and qualifications, and quoting the reference RIS.

Physicists

Simon-Carves Ltd.

require physicists for research work in a number of fields—fluidization, flame combustion, electro-precipitation, small particle behaviour, reaction kinetics, applied thermodynamics and pneumatic techniques.

Candidates should be university graduates or have professional qualifications of Associate Membership standard.

Salaries will be in the range £750–£1,250, depending on experience.

The posts are at Stockport. Working conditions are excellent ; scope is good ; a pension scheme is in operation.

Please send brief relevent application (quoting ref DM38A) to Staff and Training Division, Simon-Carves Ltd., Cheadle Heath, Stockport.

(*Continued on page vii*)

The British Petroleum Company Limited invites applications from young Graduates with a degree in Engineering, Physics, Mathematics or Natural Philosophy, to be trained as Petroleum Engineers. Training will last for approximately 2 years and will take place partly in the United Kingdom and partly overseas. On successful completion of the training, men will be posted as **Resident Petroleum Engineers** to exploration areas overseas. Age preferably not over 26, National Service obligations must have been fulfilled. Write stating age and full details of qualifications and experience quoting H.2089 to Box 7649, c/o 191 Gresham House, E.C.2.

Large British Oil Company has vacancies for **geophysicists** on its exploration staff. Candidates should have an honours degree in physics with subsidiary mathematics and/or geology, but candidates with a general degree will be considered. The work involves delineation of underground rock structure by seismic, gravitational and magnetic techniques and offers considerable scope for men with initiative who are prepared to travel and to work abroad. Normal leave is four months after two years' foreign service.

When conditions permit, facilities are afforded for married men to have their families with them on foreign tours.

Basic salary is commensurate with age and experience, commencing at £870 for young, inexperienced graduates. Appropriate allowances are paid whilst on foreign service. Generous pension scheme.

Applications quoting F.107, should be addressed to Box 1442, c/o 191 Gresham House, E.C.2.

Physicist or **Electrical Engineer** required in Research and Development Laboratory in the North of England to take charge of development group working on discharge lamps including fluorescent tubes and control gear. Experience in lamps or kindred branches of electronics or high vacuum work desirable. Essential to possess ability to supervise development. Excellent prospects for a man making a career in industry. Pension scheme. Send full particulars of education and experience to Box No. 82, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

University of St. Andrews
Queen's College, Dundee
Lectureship in Physics

Applications are invited for appointment as Lecturer in the Department of Natural Philosophy, Queen's College, Dundee, commencing 1st October, 1955. Salary scale £560 × £50 per annum to £1,350, with efficiency bar at £1,000, and commencing salary according to experience and qualifications. F.S.S.U. and family allowance benefits; grant towards expenses of removal may be made. Applications, with names of three referees, to the undernoted, not later than Saturday, 30th July, 1955.

Patrick Cumming,
Joint Clerk to the University Court,
Queen's College, Dundee.

Rolls-Royce Limited require Technical Staff for a new research project. The work will be original and interesting and in pleasant surroundings near Derby.

There are vacancies for **Technical Staff** with degrees in Engineering, Physics or Mathematics, for theoretical and experimental work: also for **Designer-Draughtsmen** with Higher National Certificate and some experience in original work. Written applications stating age, qualifications and experience to Labour Manager (OHJ), P.O. Box 31, Derby.

Louis Newmark Ltd. have a vacancy in their laboratories for a **Physicist** or **Electro-Mechanical Engineer** for development work on aircraft and allied instruments. Applications are invited from persons with a degree or similar qualifications who have had some industrial experience preferably on work with gyroscopes or accelerometers. Good salary and prospects. Apply Personnel Manager, Louis Newmark Ltd., Prefect Works, Purley Way, Croydon, Surrey.

ASSISTANTS

Northampton Polytechnic, London, E.C.1

Chief Laboratory Technician for Applied Physics required. Knowledge of physics and laboratory and workshop experience necessary. Post involves assisting in development of laboratories and also some responsibility for junior staff.

Preference given to man keen on continuing his studies. Five weeks paid holiday annually. Superannuation scheme. Scale: £503 by £25 10s. to £580 per annum. Apply by letter to the Secretary.

Wolverhampton and Staffordshire
Technical College
Principal: C. L. Old, B.Sc. (Eng.), M.Sc. (Tech.)

Applications invited for **Senior Laboratory Assistant,** Physics Section of Department of Applied Science.

Applicants should be not less than 25 years of age, have completed or be exempt from National Service, have had good industrial, including workshop, or other laboratory experience, be able to undertake supervision of juniors, maintain laboratory equipment and control stores.

Superannuable post. Medical examination. Salary and conditions Grade IV Miscellaneous scales, £465 – £545 per annum.

Apply by letter to Principal, Wolverhampton and Staffordshire Technical College, Sulfruna Street, Wolverhampton, giving age, education, qualifications and experience, and two persons to whom reference may be made.

G. W. R. Lines,
Clerk to the Joint Education Committee.

MEMBERS' ADVERTISEMENTS

Chartered Patent Agent (B.Sc., A.Inst.P.): professional services available. Box No. 80. The Institute of Physics, 47 Belgrave Square, London, S.W.1.

COURSES

The Polytechnic, Regent Street, W.1
Department of Mathematics and Physics

Full-time and evening courses for Intermediate B.Sc. General in Pure mathematics, physics and applied mathematics or statistics, B.Sc. Special External Degree of London University in physics and Grad.Inst.P. Evening Courses in statistics, electronics, techniques of mathematical physics, advanced mathematics for Special Degree and Postgraduate Studies.

Prospectus available from the Director of Education.